Tests Methods for Determination of Moisture Damage

San Diego, California
February 4-6, 2003

Mansour Solaimanian
Pennsylvania State University

John Harvey
University of California at Davis

Maghsoud Tahmoressi
PaveTex Engineering & Testing

Vivek Tandon
University of Texas at El Paso

Outline

- Historical Development
- Types of Tests
- Description of Tests
- Significance and Use
- Summary

Historical Development

Historical Development

Dates back to 1930's:

- Nicholson
- Riedel & Weber
- Lee
- McLeod
- Hubbard
- Powers
- Winterkorn
- Saville & Axon (Boil Test)
- Nevitt & Krchma

Historical Development

1940's:

Krchma and Nevitt (Absorption Effects)
Hveem (awareness)

1950's:

Hallberg (Water Pressure – Pore Size Effect)
Rice (Aggregate Characteristics – ASTM STP 240)
Thelen (Surface Energy – HRB 192)
Andersland and Goetz (Sonic Test)
Goode (Immersion Compression)

Historical Development

1960's:

Majidzadeh and Brovold (State of the Art)
Johnson (Thermally Induced Pore Pressure)

1970's:

Ford (Surface Reaction Test)
Jimenez (Pore Pressure – Double Punch)
Lottman (Freeze-Thaw, Indirect Tensile)
Maupin (Implementation)
Plancher et al (Asphalt Chemistry)
Schmidt and Graf (Resilient Modulus)

Historical Development

1980's:

Plancher et al (Freeze-Thaw Pedestal Cycling)
Coplantz and Newcomb (Comparison of Tests)
Isacsson and Jorgnesen
Kennedy, Anagnus, Roberts, Lee (Boil, Freeze-Thaw Pedestal)
Tunnicliff and Root (Indirect Tensile)
Collins, Lai (Asphalt Pavement Analyzer)
Parker (Evaluation of Tests)
Stuart (Evaluation of Tests)

Historical Development

1990's:

Hicks, Terrel, Scholz, Al-Swailmi (ECS)
Aschenbrenner, Tahmoressi (HWTD)
Tandon (Modified ECS)
Curtis, Ensley, Epps (Net Adsorption Test)
Kendhal (Plastic Fines, MBT)
Youtcheff (Pneumatic Pull-Off)

Historical Development

2000's:

Harvey, Monismith, and Bejarano (APT-Field Testing)
Cheng, Little, Lytton, Holtse (Surface Energy)
Robertson, Thomas. … (Asphalt Chemistry, Ultrasonic, Centrifugation)
Solaimanian, Tandon, Bonaquist (SPT/ECS)
Mallick, Regimand (Cyclic Pressure/Suction)

Historical Development

Boil Test (1930's, 1980's)

Immersion Compression (1950's)

Freeze-Thaw Conditioning with Strength Test (1970's, 80's)

Freeze-Thaw Pedestal Test (1980's)

Hamburg Wheel Tracking Device (1970's, 1990's)

Asphalt Pavement Analyzer (1980's, 1990's)

Environmental Conditioning System (SHRP, 1990's)

ECS/SPT (2000's)

Types of Tests

Types of Tests

- **Two Major Categories**
  - ✓ **Tests on Loose Asphalt-Aggregate Mixtures**
  - ✓ **Tests on Compacted Specimens**

Tests on Loose Mixtures

Examples:

Boil, Static/Dynamic Immersion, Rolling Bottle

Advantages:

Simpler Equipment, Simpler Procedure, Less Costly, Screening for Compatibility

Disadvantages:

Results mostly qualitative

Subjective Interpretation (evaluator's experience)

Not taking into consideration traffic, environment, and mix properties

Tests on Compacted Mixtures

Examples:

- Immersion-Compression,
- Freeze-Thaw Cyclic with Strength/Modulus Measurement

Advantages:

- Taking into consideration traffic, environment, and mix properties
- Results can be quantified

Disadvantages:

- More elaborate testing equipment
- Longer Testing Time
- More laborious test procedure
- More expensive

Tests on Loose Material

Test Method	ASTM	AASHTO
Methylene Blue		
Static Immersion	D 1664	T 182
Dynamic Immersion		
Chemical Immersion		
Surface Reaction		
Boiling	D 3625	
Rolling Bottle		
Net Adsorption		
Surface Energy		
Pneumatic Pull-Off		
Ultrasonic		

Tests on Compacted Specimens

Test Method	ASTM	AASHTO
Moisture Vapor Susceptibility		
Immersion Compression	D 1075	T 165
Marshall Immersion		
Freeze-Thaw Pedestal		
Original Lottman		
Modified Lottman		T 283
Root-Tunnicliff	D 4867	
Cyclic Pressure/Double Punch		
ECS/Res. Mod.		
Hamburg Wheel Tracking		
Asphalt Pavement Analyzer		
Beam Fatigue		
ECS/SPT		
Ultrasonic		

Test Methods

Test Methods

Methylene Blue Test

- ✓ French test
- ✓ ISSA recommendation
- ✓ Quantify amount of harmful clay in fine agg.
- ✓ Higher MBV ⟶ Higher Clay Content
  Higher Susceptibility to Moisture Damage
- ✓ Relatively good correlation with TSR and SIP
  (Kendhal, 1998)

Test Methods

Static Immersion (AASHTO T 182) (ASTM D 1664)

100 grams of uniform size aggregate (6.3 – 9.5 mm)

Coat with binder

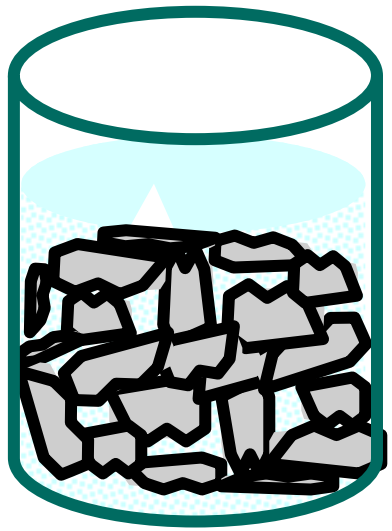
Cure at 60°C for 2 hrs

Cover in jar with distilled water

Remain immersed for 16-18 hours

Conduct visual inspection

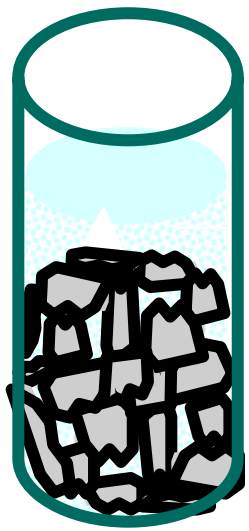
Criteria: 95 percent retained coating



Test Methods

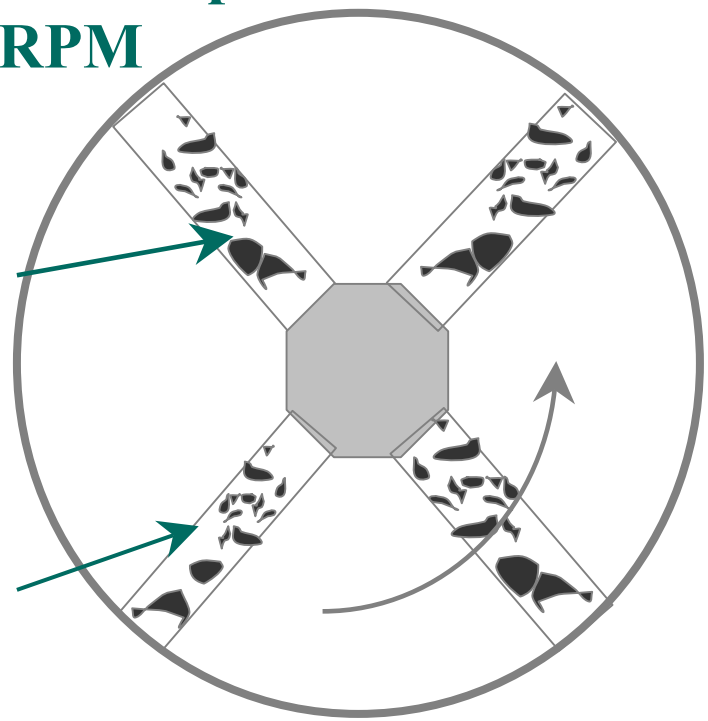
Film Strip Test (CA Test 302)

Cure coated aggregate at 60°C for 15-18 hrs
Cover in jar with distilled water and cap
Rotate the jar for 15 min. at 35 RPM
Conduct visual inspection



Asphalt Coated Aggregate and Water

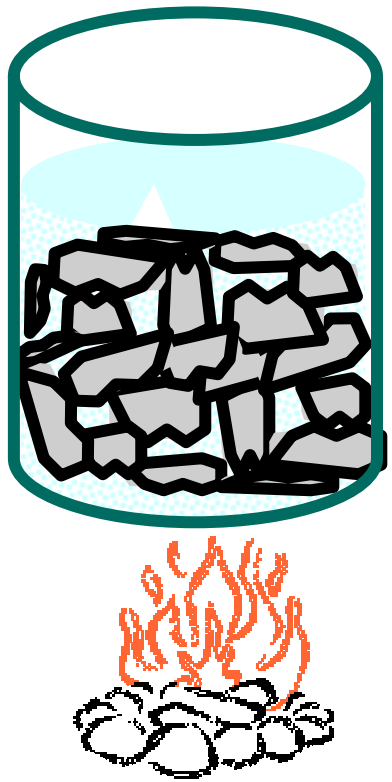
Capped Jar



Test Methods

Boil Test
(ASTM D 3625)

250 grams of coated aggregate
Place in boiling water
Bring water back to boiling
Maintain boiling for 10 minutes
Cool to room temp. and decant water
Empty on white paper towel
Conduct visual inspection



Test Methods

Net Adsorption Test (SHRP A-341, A-402)

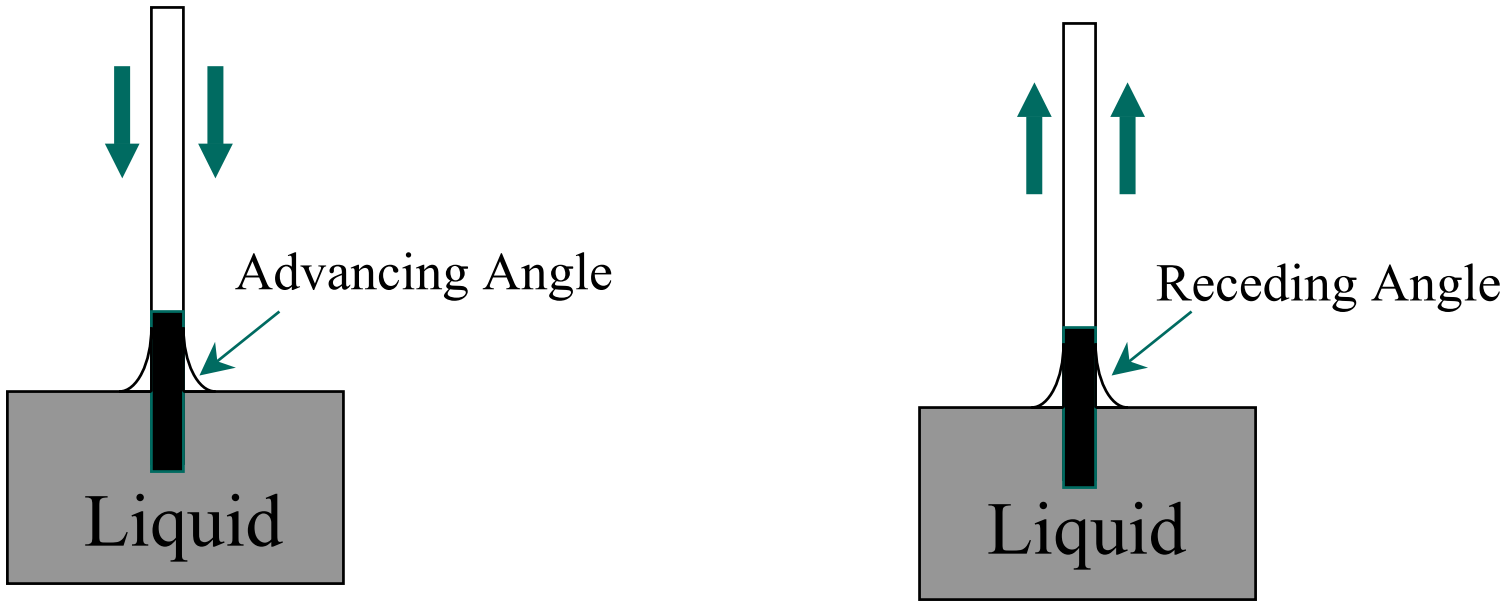
50 grams of aggregate passing #4 sieve
Dry aggregate in a 135°C oven for 15 hours
Adsorb asphalt into aggregate from toluene solution
Apply water
Desorb asphalt from aggregate

Determine net adsorption

Test Methods

Surface Free Energy

Wilhelmy Plate Test (SFE for Asphalt Binder)
(DingXin, Little, Lytton, and Holtse, 2002)



Universal Sorption Device (SFE for Aggregate)

Test Methods

Surface Reaction Test

Chemical reaction between agg. surface and agent creating pressure

Ultrasonic Test

Both on loose and compacted mixtures

Pneumatic Pull-Off

Determine binder adhesion to a glass plate

Test Methods

For Surface Treatments

Immersion Tray Test

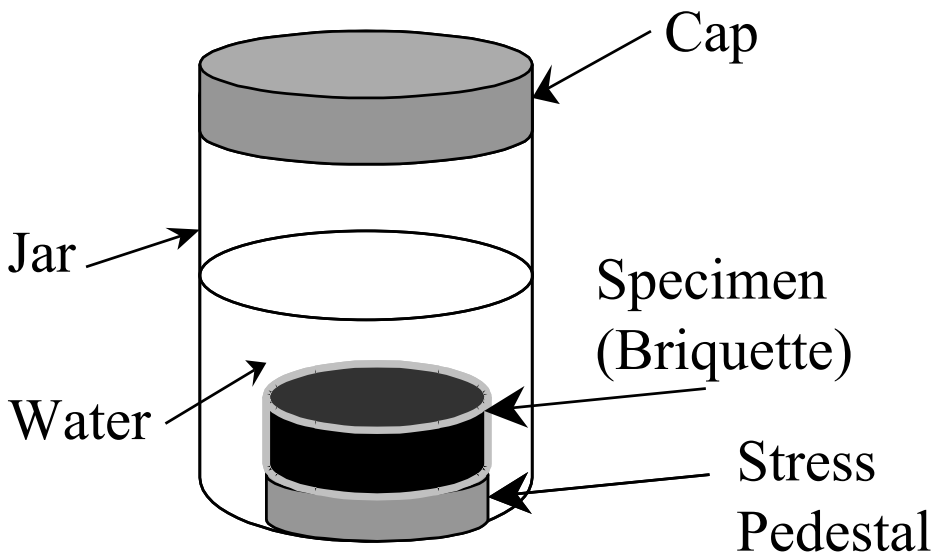
Plate Test

Sand Mix Test

Test Methods

Freeze-Thaw Pedestal Test

Uniform size aggregate (0.50 – 0.85 mm)
Two hours curing at 150°C before compaction
Compact under 28 KN to 19 mm X 41 mm
Cure for three days at room temp.
Thermal Cycling –12°C (15 hrs), 49°C (9 hrs)



Test Methods

Immersion Compression

Goode (1950's)

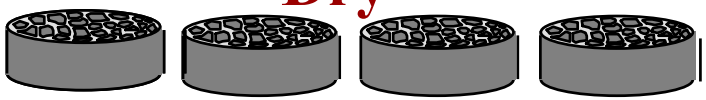
ASTM D 1075, AASHTO T 165

Compressive Strength Ratio

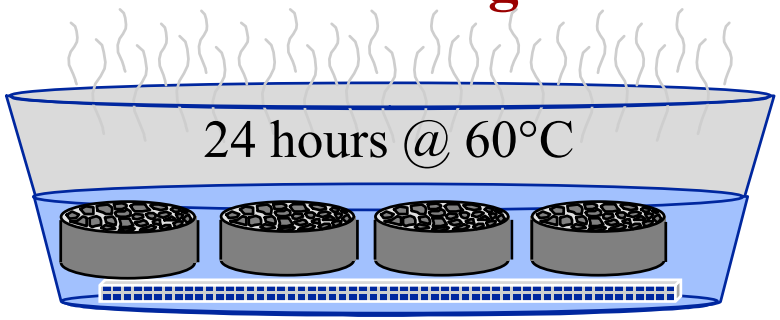
Test Methods

Immersion Compression

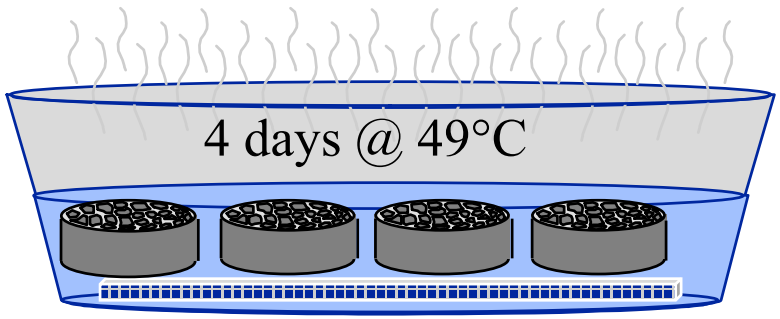
Dry

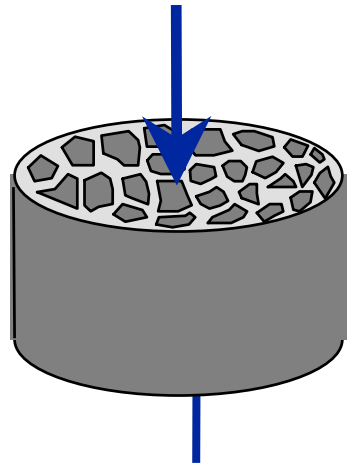


Conditioning



OR





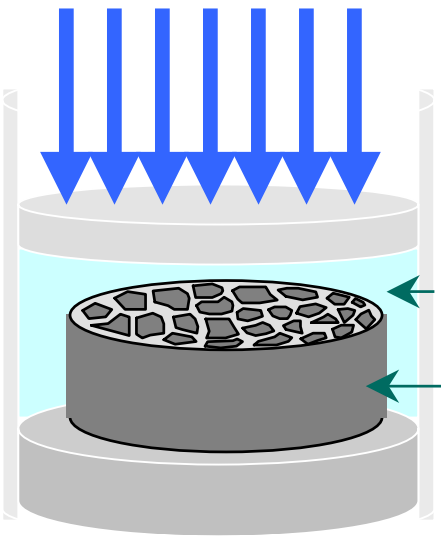
Specimens:
101 x 101 mm
Approx. 6% Voids

Index of Ret. Strength = S2/S1

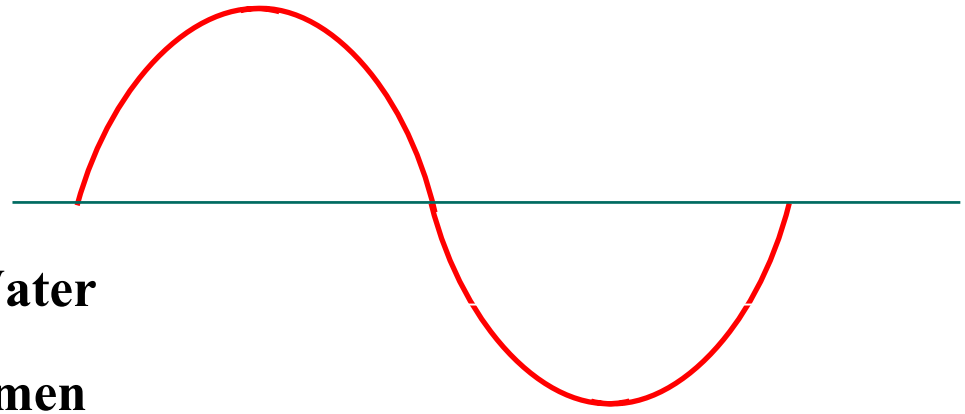
Test Methods

Cyclic Water Pressure with Strength Test
(Jimenez, 1974)

Cyclic Pressure



Sinusoidal Loading
(Hydraulic Pressure 5-30 psi)

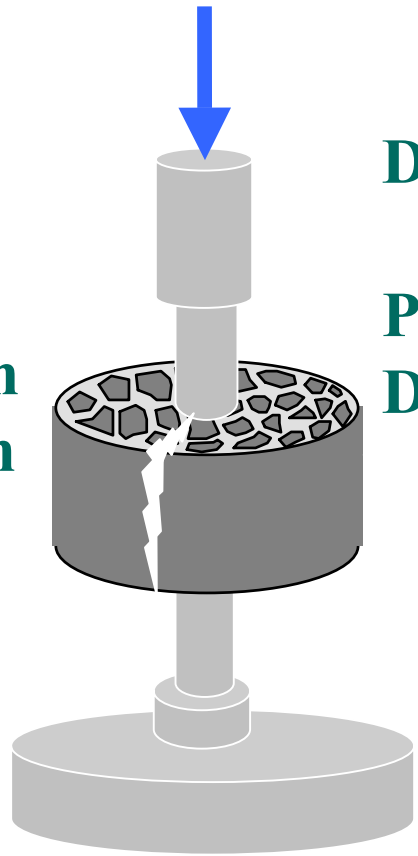


Test Methods

Double Punch Test
(Jimenez, 1974)

Test Temp.: 25°C

Specimen Size:
H: 50, 101, 203 mm
D: 50, 101, 152 mm



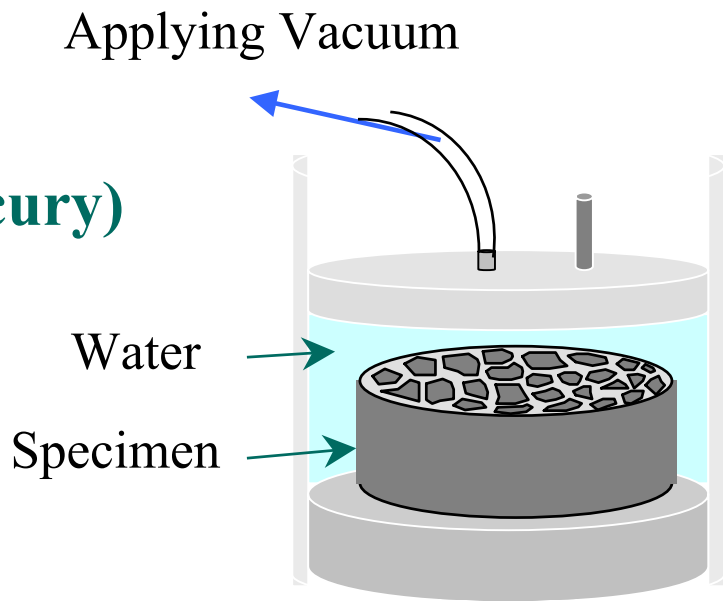
Derform. Rate: 25 mm/min

Punch Diameter:
D: 10, 16, 24 mm

Test Methods

Original Lottman Test
NCHRP 192, 1978)
NCHRP 246, 1982)

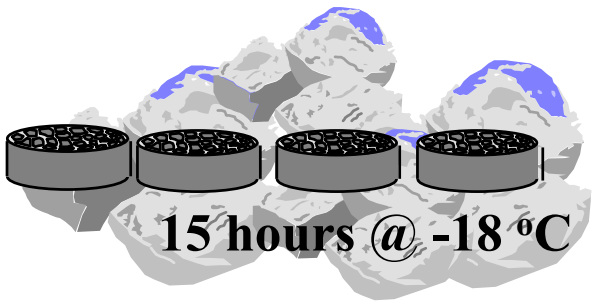
Conditioning
(Vacuum Saturation –
30 minutes under 4 inches of mercury)



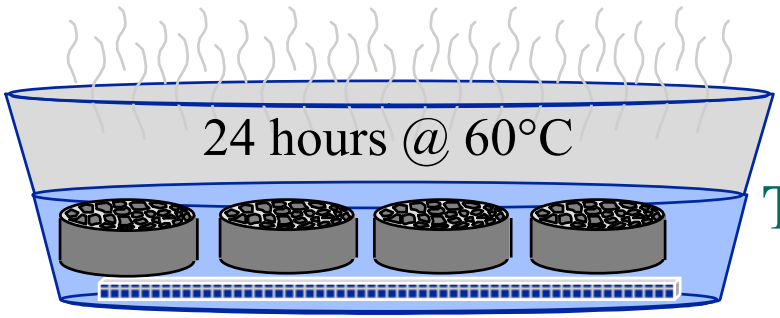
Test Methods

Original Lottman Test

Conditioning (Freeze-Thaw)

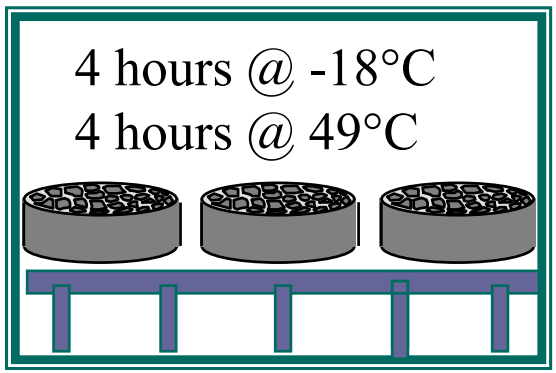


Freeze



Thaw

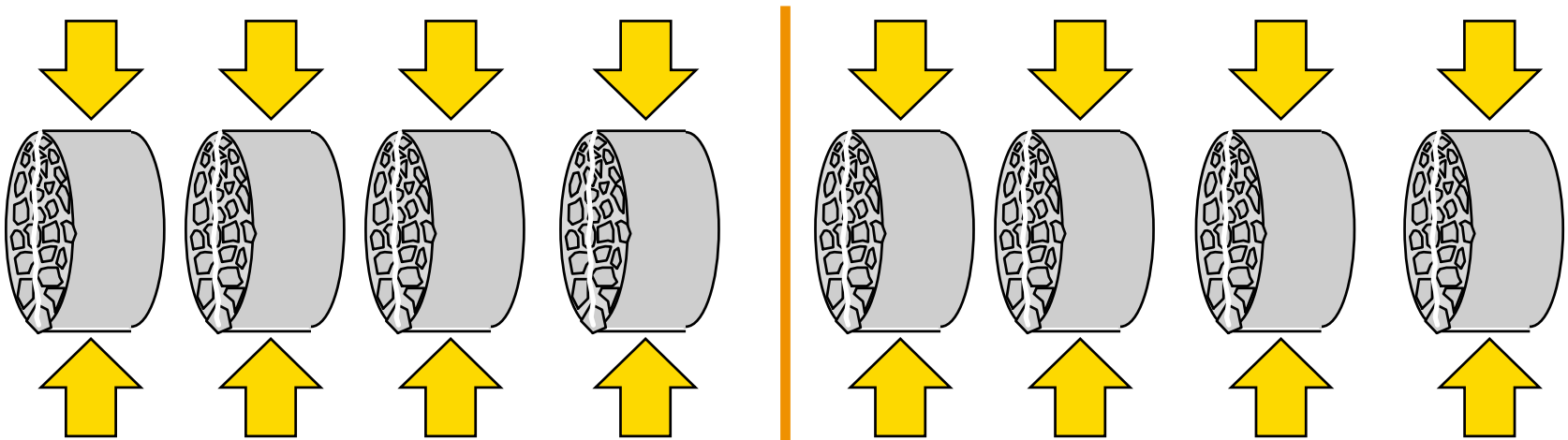
Conditioning (Thermal Cycling) For 18 Cycles



Test Methods

Original Lottman

(1.7 mm/ min @ 13°C OR 3.8 mm/ min @ 23°C



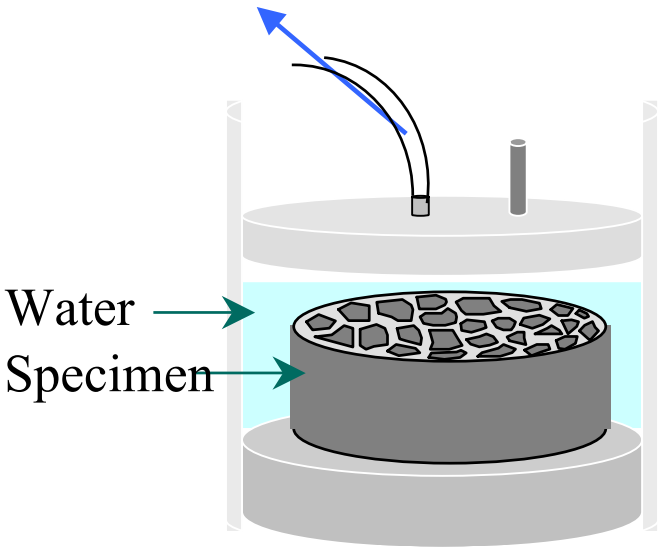
Avg Dry Tensile Strength | **Avg Wet Tensile Strength**

$$TSR = \frac{\text{Wet}}{\text{Dry}} \geq 70\ \%$$

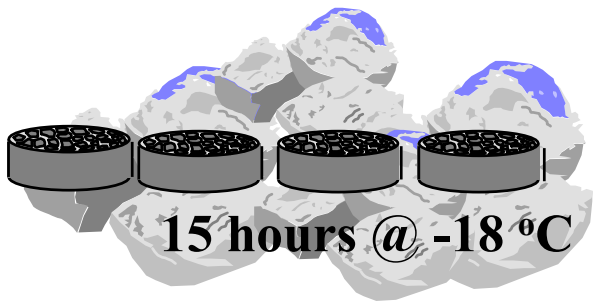
Test Methods

Modified Lottman Test (AASHTO T 283)

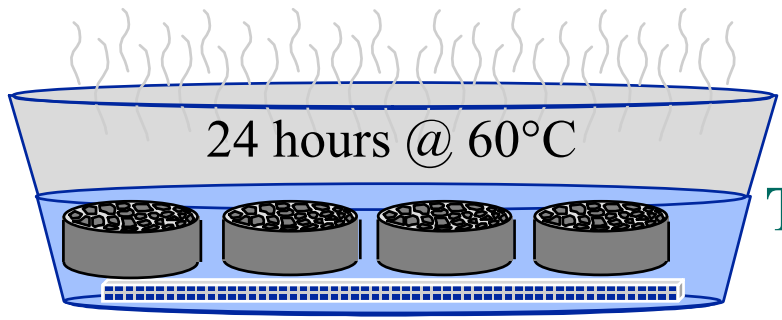
Applying Vacuum
55 to 80% Sat. (70 to 80%?)



Conditioning (Freeze-Thaw)



Freeze

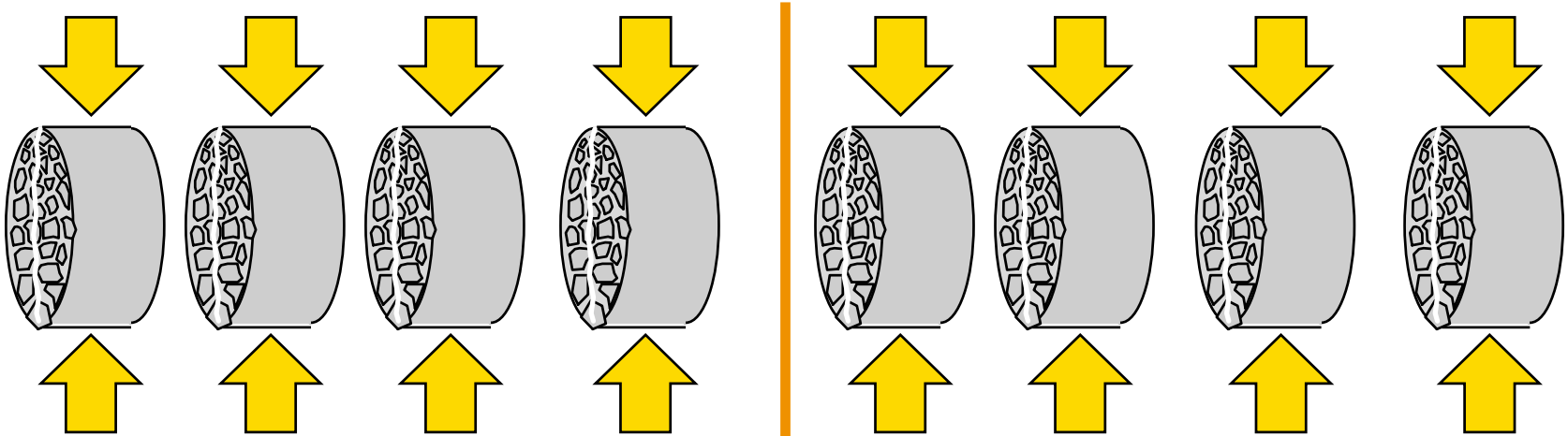


Thaw

Test Methods

Modified Lottman Test (AASHTO T 283)

51 mm / min @ 25 °C



Avg Dry Tensile Strength | **Avg Wet Tensile Strength**

$$TSR = \frac{Wet}{Dry} \geq 80\ \%$$

Test Methods

Hamburg Wheel Tracking Device (HWTD)

- **TxDOT Procedure**
  - ✓½” Rut Depth
  - ✓ Test Temp.: 50 °C
  - ✓# of Passes: 20,000

Test Methods

Hamburg Wheel Tracking Device (HWTD)

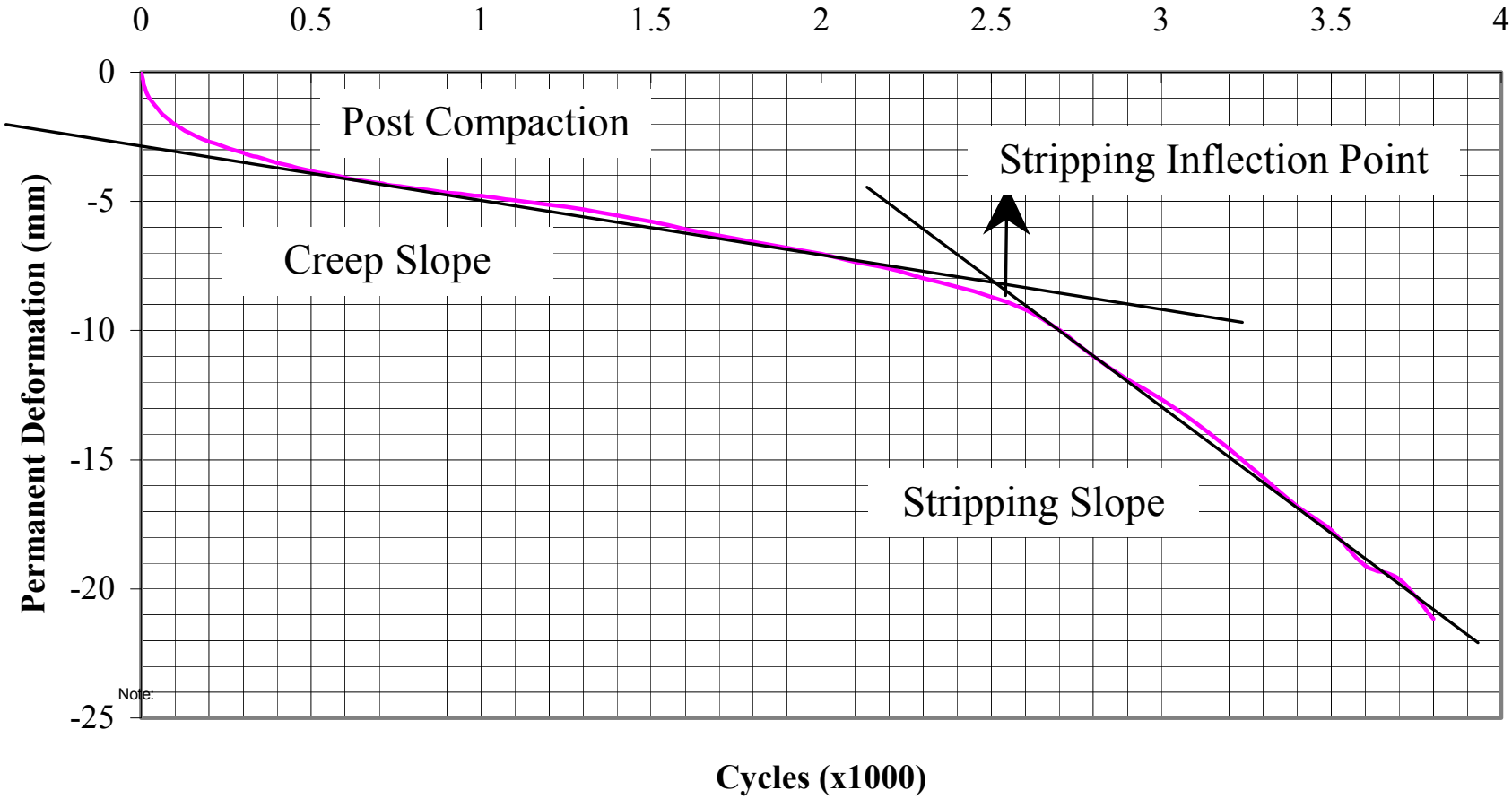
Two Cylindrical Specimens

Test Methods

Hamburg Wheel Tracking Device (HWTD)

Test Methods

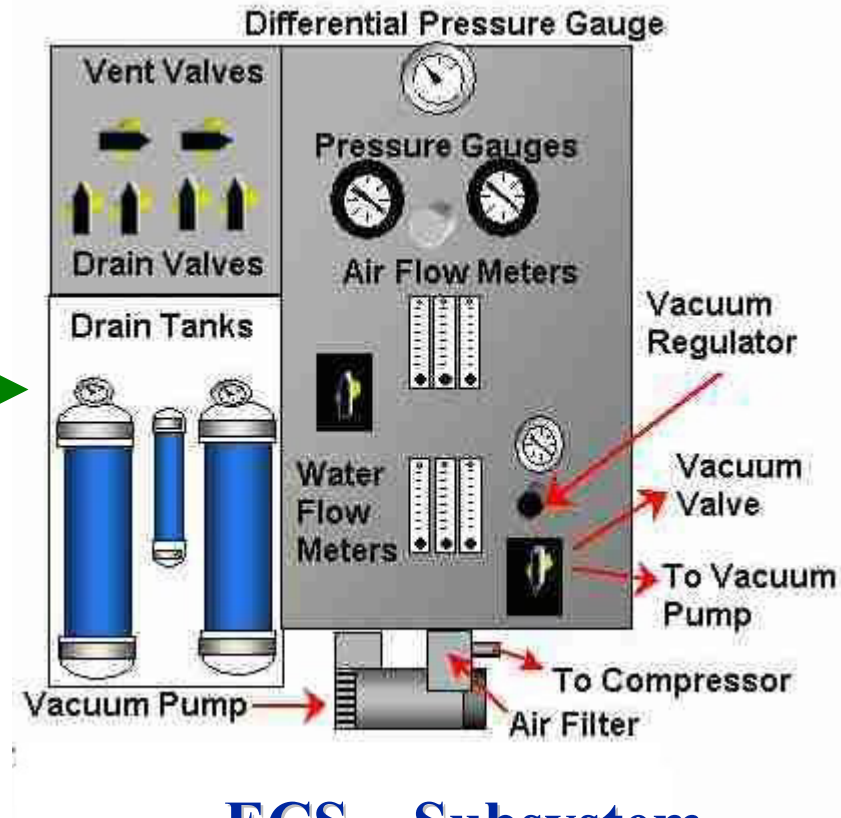
Hamburg Wheel Tracking Device (HWTD)



Test Methods

ECS/SPT System

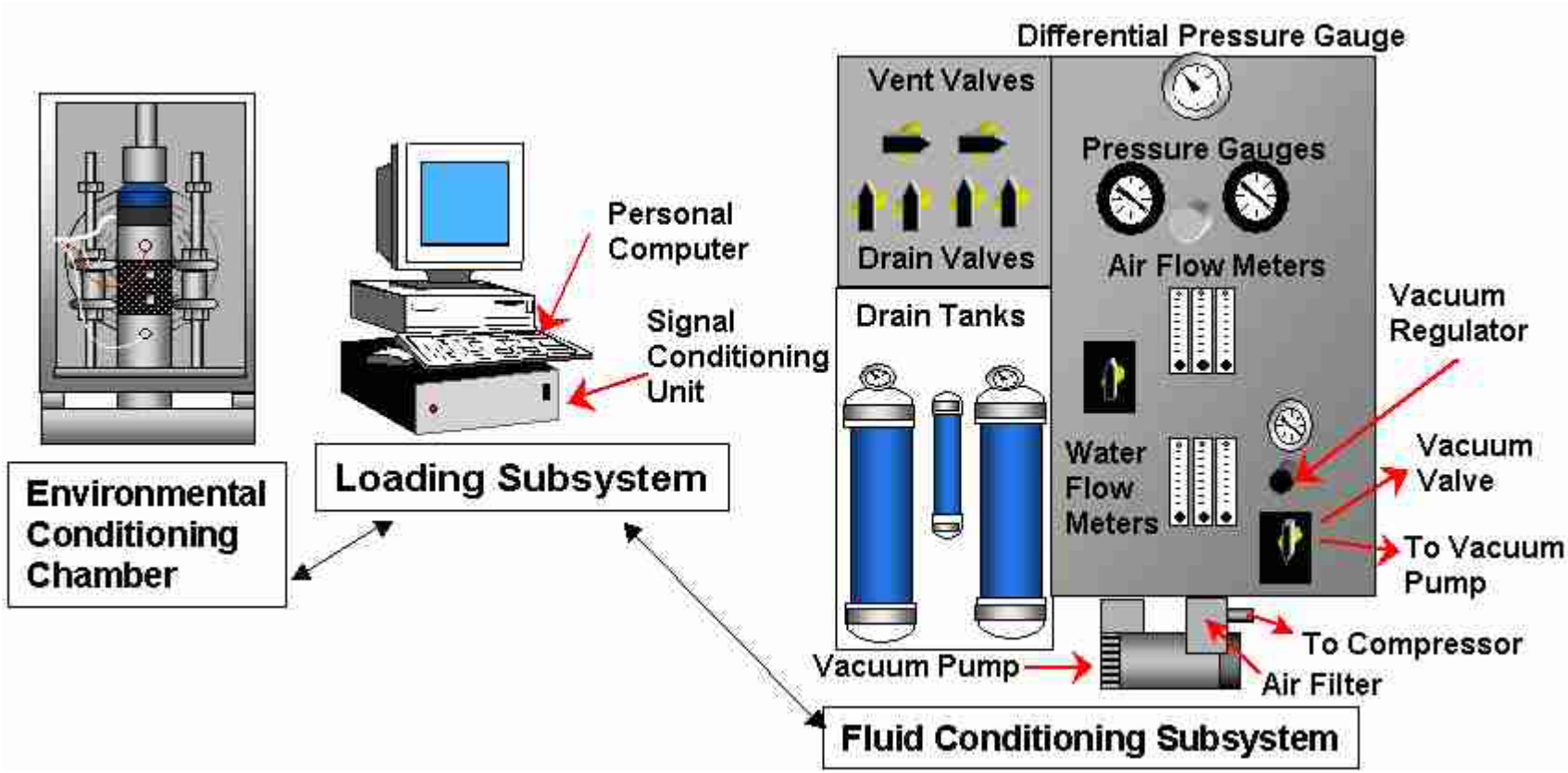
SPT
(Simple Performance Test)



ECS – Subsystem
Environmental Conditioning System

Test Methods

Environmental Conditioning System



Test Methods

ECS/SPT System

- ECS Developed at OSU as part of SHRP A-003A
- SHRP Period 1987-1993
- Improved at UTEP under TxDOT Project
  - ✓Repeatability
  - ✓Rigidity
  - ✓Strain Measuring System
  - ✓Controlling Water Temperature
  - ✓Confining Pressure

Current ECS Testing

Measure Resilient Modulus before and after Conditioning

- **Specimen Size: Dia: 100 mm, H: 100 mm**
- **Conditioning Temperature** 60 °C
- **Confining Pressure** 2.5 inches of mercury
- **Conditioning Time** 6-18 hours
- **Conditioning Load** 200 lbs
- **Haversine Load**
  - ✓50 to 100 Microstrain
  - ✓0.1 sec loading period – 0.9 sec rest period

Test Methods

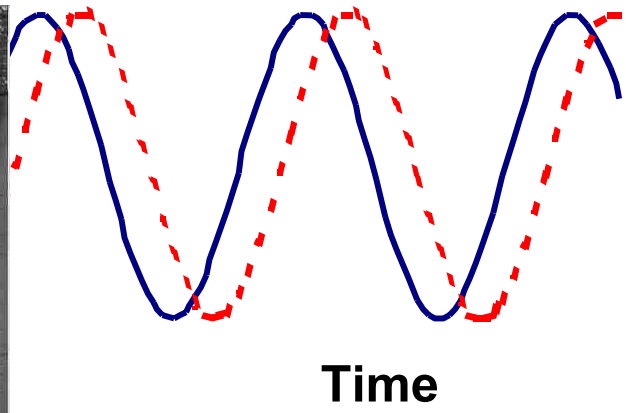
Simple Performance Tests

Candidate Tests

- Dynamic Modulus
- Creep Test (Flow Time Test)
- Repeated Load Test (Flow Number Test)

Test Methods

Dynamic Modulus Test



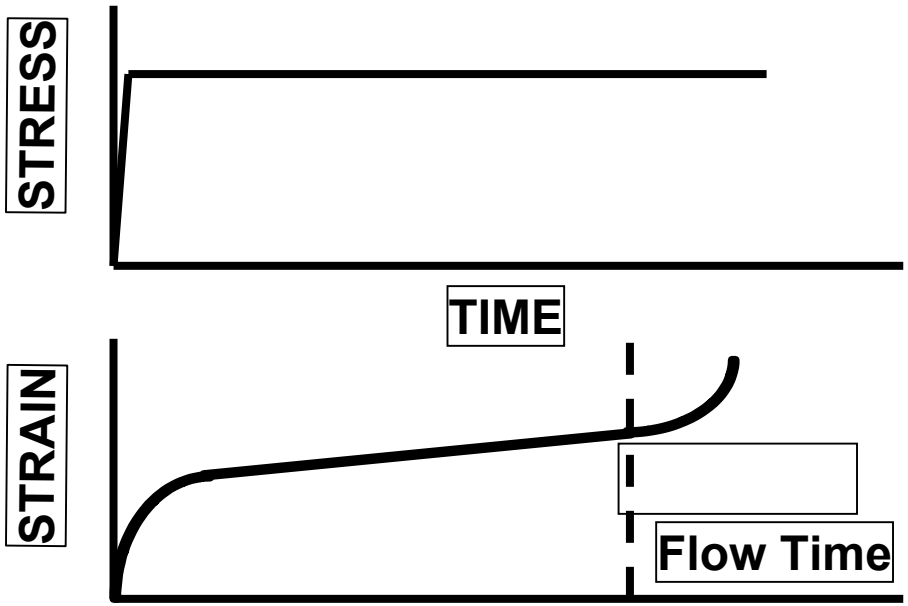
$$|E^*| = \frac{\sigma_0}{\varepsilon_0}$$

Rutting

Fatigue Cracking

Test Methods

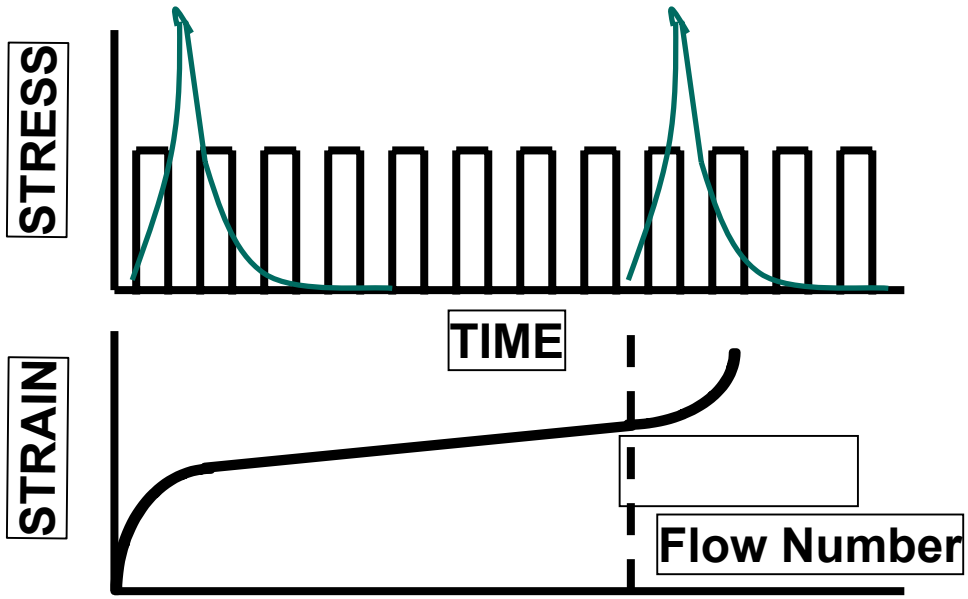
Creep Flow Time Test



Rutting

Test Methods

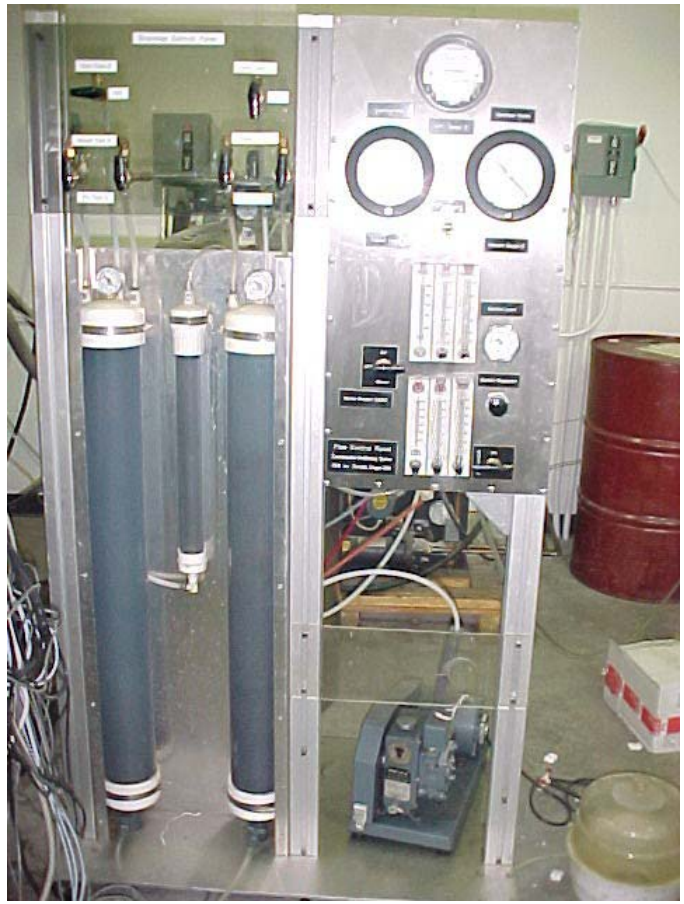
Repeated Load Perm. Deformation Test



Rutting

Test Methods

ECS/SPT System



Test Methods

ECS/SPT System

Using Tests
And
Their Significance

Tests in Use

Before SHRP

Test Method	No. of Agencies
Boiling Water (ASTM D 3625)	9
Static Immersion	3
Original Lottman	3
Modified Lottman (AASHTO T 283)	9
Tunnicliff-Root (ASTM D 4867)	9
Immersion Compression (AASHTO T 165)	11

After Hicks (1991)

Tests in Use

After SHRP

Test Method	No. of Agencies
Boiling Water (ASTM D 3625)	0
Static Immersion	0
Original Lottman	3
Modified Lottman (AASHTO T 283)	30
Tunnicliff-Root (ASTM D 4867)	6
Immersion Compression (AASHTO T 165)	5
Wheel Tracking	2

After Aschenbrenner (2002)

Success of Tests

Test Method	Criteria	% Success
Boiling Water	Ret. Coat. = 85-90%	58
Modified Lottman	TSR = 70%	67
	TSR = 80%	76
Tunnicliff-Root	TSR=70%	60
	TSR=80%	67
Immersion Compression	Ret. Strength=75%	47

After Kiggundu and Roberts (1988)

Key Items for A Successful Test

Key Items for a Successful Test

- ✓ Repeatable and Reproducible
- ✓ Feasible, Practical, Economical
- ✓ Good Discriminator
- ✓ Good Simulator of Field Mechanisms

Implementation

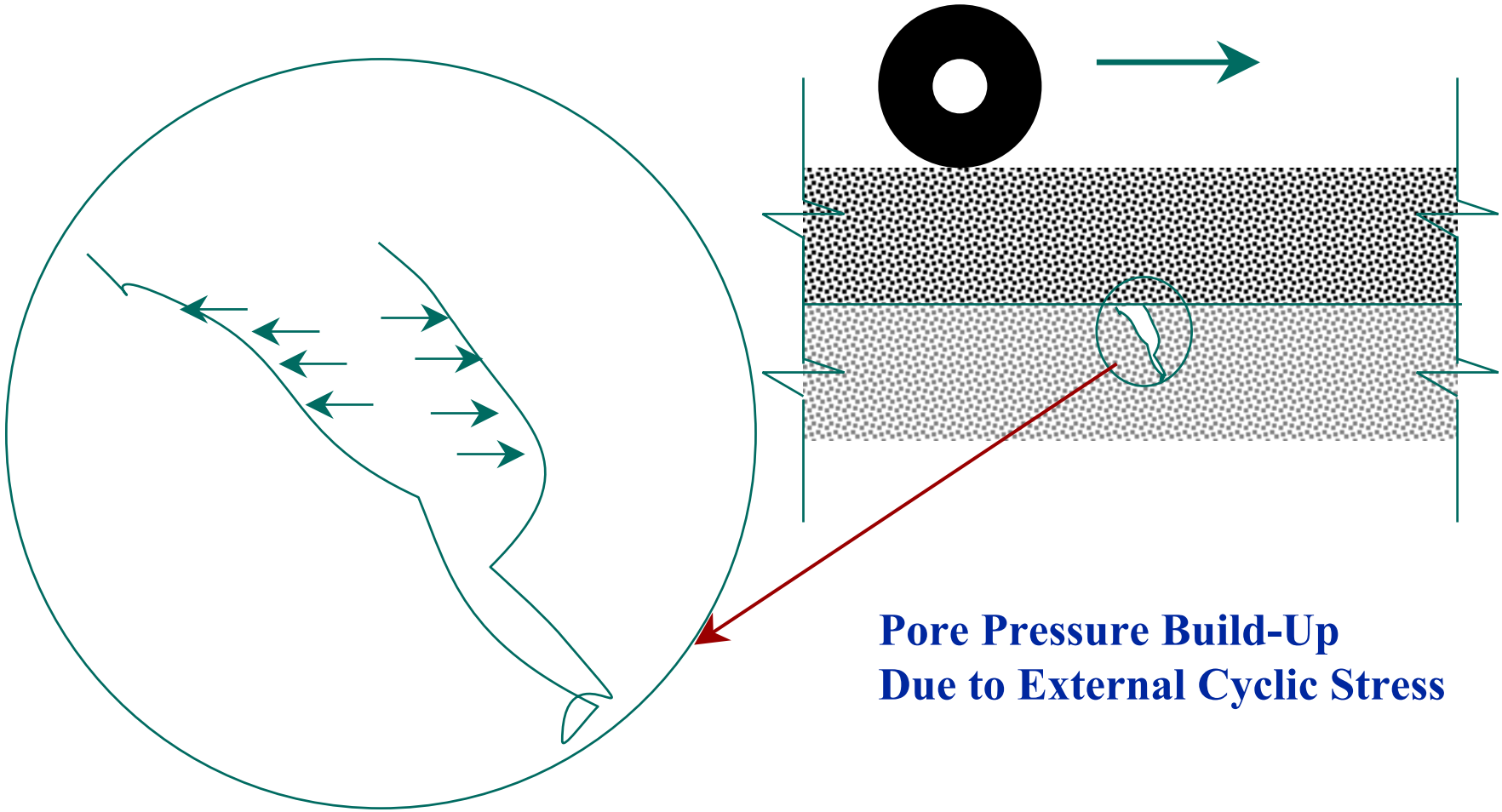
- **Calibration to Field Conditions**
  - ✓ **Success/Failure is Site Dependent**
  - ✓ **Important Issue Is Correlation**
  - ✓ **Develop Database – Mix, Traffic, Structure Data**
  - ✓ **Quantifying Field Performance Is Difficult**

What Is Important?

compatibility, mix, traffic, and environment

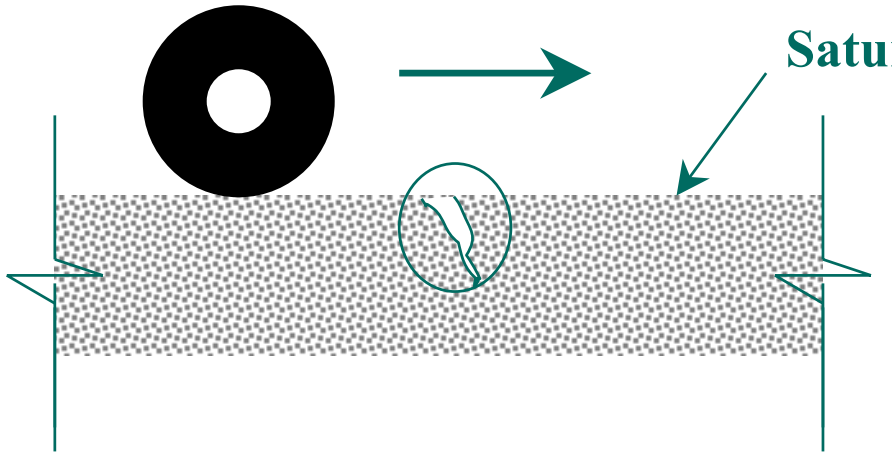
- ✓ **Binder Content**
- ✓ **Binder Stiffness**
- ✓ **Air Void Level and Size**
- ✓ **Connectivity of Voids**
- ✓ **Traffic Effect: Pumping & Hydrostatic Pressures**

Pore Pressure Effect



Pore Pressure Build-Up
Due to External Cyclic Stress

Hydraulic Scouring



Compression/Tension Cycle

Stripping Starts at the Surface Progressing Downward

Summary

Summary

- **Research on Moisture Damage Tests: 1930's**
- **Two Types of Tests Have Been Developed:**
  - ✓ **On loose mixture and materials**
  - ✓ **On compacted specimens**
- **Tests on Loose Mixtures**
  - ✓ **Good for initial screening**
  - ✓ **Relative success of various antistripping agents**
- **Tests on Compacted Specimens**
  - ✓ **Some capture field conditions better than others**

Summary (Cont'd)

- **AASHTO T 283 Is Currently the most Widely Used Procedure**
- **Loaded Wheel Testers Are Gaining Considerable Popularity**
- **Field Conditions Are Important – No Universal Protocol Can Be Applied to All Conditions**
- **Tests Should Be Calibrated for Field Conditions**

Thank You!